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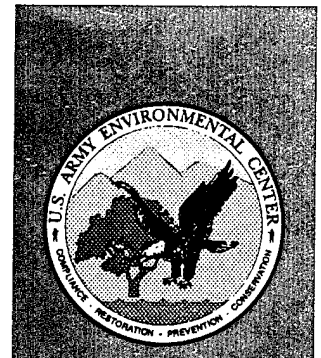

U.S. Army Environmental Center

Composting of Nitrocellulose Fines - Regulatory and Logistical Feasibility - RAAP Installation

Report No. SFIM-AEC-ET-CR-95086
Contract No. DACA31-91-D-0079
Task Order No. 0011

December 1995

Prepared for:
U.S. Army Environmental Center (USAEC)
SFIM-AEC-ETD
Aberdeen Proving Ground, MD 21010-5401

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The production of nitrocellulose for munitions purposes results in the production of nitrocellulose fines (NC fines). RAAP currently produces approximately 1,250 lbs/day of NC fines (dry basis). Composting has been evaluated as a means of managing these fines and yielding a nonreactive beneficial soil amendment.

This report describes the logistical and regulatory feasibility and the following end-use options for the compost: (1) land application (with harvesting) by the installation; (2) providing local farmers with compost as a soil amendment; (3) land application of finished compost to reclaim land that mining operations have disturbed; and (4) disposal at a landfill. All options were found to be feasible with regard to regulatory constraints. Because finished NC compost is not specified in federal or Virginia State regulations for solid waste, the nonhazardous nature of the compost needs to be assured through demonstration of nonreactivity and/or chemical content determination. Based on predicted application rates, the anticipated 450 tons/year of compost would require approximately 320 acres/year of land. Based on preliminary site selection criteria, these land requirements appear to be achievable. Costs per ton of compost range from $20/ton for supply to local farmers to $100/ton for application by the installation.

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EXECUTIVE SUMMARY

The production of nitrocellulose for munitions purposes results in the production of nitrocellulose fines (NC fines). The Army is evaluating methods to recover these NC fines or recycle them into usable products. An alternative for the management of nonrecoverable NC fines derived from the production of nitrocellulose is biological treatment via composting. Previous pilot testing at Badger Army Ammunition Plant (BAAP) indicated that NC can be degraded via composting. Composting has the potential to eliminate the reactivity characteristic of NC fines. It also has the advantage of yielding a beneficial finished compost suitable for use as a soil amendment.

Currently, NC fines are being produced at RAAP at rate of approximately 1,250 lb/day on a dry basis. Previous reactivity testing has shown that NC fines in a compost matrix with a moisture content of 30%, at loading rates between approximately 10 and 35%, may be handled safely.[12] Further, the composting process was determined to be economically feasible, at a cost of approximately $310/yd^3 of NC fines.[12]

The composting process is anticipated to yield a nonreactive soil amendment suitable for beneficial reuse. This report describes the logistical and regulatory feasibility of the following end-use options:

- Land application (with crop harvesting) by the installation.
- Providing local farmers with compost as a soil amendment.
- Land application for reclaiming lands disturbed by mining.
- Landfilling the finished NC fines compost.

All of these end-use options were found to be feasible with regards to regulatory constraints, including buffer zone and application rate restrictions and various permitting requirements. However, as finished NC compost is not specifically mentioned in federal or Virginia state regulations for solid waste, nonreactivity needs to be demonstrated and chemical content determined to assure the nonhazardous nature of the compost.

To apply the anticipated 450 tons/year of finished compost, approximately 320 acres/year of land will be needed, based on predicted application rates. Table ES-1 presents approximate annual costs for each end-use option. Based on preliminary site selection criteria such as slope, current land use, and proximity to the RAAP installation, it appears that adequate land exists in the vicinity of the installation and at the installation itself to satisfy the acreage requirements. Properties would have to be evaluated on an individual basis prior to final selection. Additionally, chemical characterization of the final compost would need to be performed to finalize application rates based on crop nutrient needs.

Table ES-1

Annual Cost Summary of End-Use Alternatives for NC Fines Compost

Alternative	Estimated Annual Cost ($/year)	Estimated Cost per Ton of Finished Compost ($/ton)[a]	Estimated Cost per Ton of Original NC Fines ($/ton)[b]
Land application by the installation	$62,500	$100	$280
Providing local farmers with compost as a soil amendment	$8,300	$20	$40
Land application for reclaiming land disturbed by mining	$33,100	$60	$150
Landfilling the finished NC fines compost	$35,700	$55	$160

[a] Based on 640 tons/year of compost, wet basis.

[b] Based on 225 tons/year of NC fines, dry basis.

SECTION 1
INTRODUCTION

1.1 BACKGROUND

The manufacture and handling of explosives and propellants at Army Ammunition Plants (AAPs) and Army Depots (ADs) have resulted in the production of various types of wastes, which require appropriate treatment and management to minimize and control their environmental impact. The U.S. Army Environmental Center (USAEC), formerly the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), has responsibility for evaluating and developing cost-effective treatment technologies to meet the goals of the Army's environmental program.

One propellant by-product for which the USAEC is evaluating treatment options is the solids, or fines, derived from the production of nitrocellulose (NC). NC is currently being produced at Radford Army Ammunition Plant (RAAP) in Radford, Virginia. Additional NC fines are also stored at the site. One technology, which the USAEC has considered for NC fines or NC fines-contaminated soil, is biological treatment via composting.

NC is a highly substituted cellulose fiber, which is synthesized from cellulosic materials such as wood pulp or cotton, and used by the Army as a propellant (alone or in combination with other constituents) in munitions and rocket motors. NC is produced from the cellulosic material by nitration using nitric and sulfuric acids, followed by various additional processing steps.[1,2] The degree of nitration can be varied by adjusting acid strength and processing conditions. As a result, NC may contain from 11.11% nitrogen (cellulose dinitrate) to a theoretical level of 14.14% nitrogen (cellulose trinitrate), although practically achievable nitrogen levels are on the order of 13.8%.[1,2,3,4] The higher nitrogen forms are primarily used in munitions, while lower nitrogen forms are used in various products in the coatings, film, ink, and adhesives industries.[1,2]

Manufacture of NC results in the production of NC fines, which are difficult to recover during production due to their small size. These NC fines have historically been discharged with process

water into lagoons. Fines that settled in the lagoons were periodically removed for recycle into product or storage.

While NC fines are not considered toxic by the U.S. Environmental Protection Agency, (EPA)[5] they may be reactive under certain conditions. The Army is investigating options to maximize both the recovery of NC fines and the recycle of NC fines into useful product.[6] The USAEC is evaluating composting as a method for treating NC fines, which have not or cannot be effectively recovered or recycled into product. Previous testing by the USAEC has shown that composting can treat NC fines in soils.[7,8]

Composting is a treatment process in which organic materials are biodegraded by microorganisms, generally at elevated temperatures. The biodegradation process results in the production of (among other things) metabolic heat, which is trapped within the compost matrix and results in so-called "self-heating" of the compost pile. As historically used for such high-organic wastes as wastewater treatment plant biosolids, municipal solid wastes (MSW), and agricultural or yard wastes, the following goals may be met by this elevated temperature process:

- Stabilization of organic matter.
- Reduction in the treated waste volume requiring further management.
- Reduction in moisture content (drying).
- Destruction of pathogenic microorganisms.

By contrast, the principal objective of composting of hazardous or chemical wastes is the efficient and rapid removal or destruction of specific regulated waste constituents or properties. Previous research conducted by USAEC has shown that a variety of nitroaromatic explosives in soils can be treated by composting.[9,10,11] Additional work has shown that the treatment of NC in soils is technically achievable.[7,8] Finally, a recent economic analysis has shown that composting of NC fines is an economically feasible treatment alternative.[12]

Due to the energetic nature of explosives and propellants, which can result in detonation under shock or thermal stimuli, safety criteria and procedures to avoid shock and thermal stimuli are of

critical importance in all materials handling aspects of treating NC. Establishing safety criteria includes considering the levels of contamination that can safely be handled in the treatment process. NC is known to be a reactive material, particularly when dry. An assessment of the levels of NC fines that can be safely handled in a compost matrix is given in *Composting of Nitrocellulose Fines - Hazards Analysis.*[12]

Because the NC fines hazards analysis report showed that composting can be economically feasible at NC fines levels considered to be safe in a compost matrix, end-use options for the finished compost also must be considered. As stated previously, EPA does not consider NC fines to be toxic.[5] Therefore, if the composting process eliminates the material's reactivity, finished NC fines compost should be able to be used as a beneficial soil amendment. As such, this report will include summaries of various end-use options and their potential costs. Also, a summary of applicable regulations for the options is included.

1.2 SITE BACKGROUND

RAAP is located in Radford, Montgomery County, Virginia, as shown in Figure 1-1. RAAP is the Army's current production facility for NC. Recent data indicate that RAAP generates about 500 to 2,000 lb/day of NC fines in process wastewater from their NC production facility.[6]

1.3 COMPOSTING OF NC FINES HAZARDS ANALYSIS RESULTS

Due to the reactive nature of NC fines, particularly when dry, an assessment of the level of NC fines that could be safely handled during the composting process was needed. To accomplish this, USAEC has conducted testing and evaluation of the reactivity of NC fines compost. Compost mixtures were developed based upon characteristics of NC fines and of amendment materials available in the vicinity of RAAP, the Army's current NC production facility. RAAP conducted reactivity testing to establish reactivity levels. NC fines loading rates between approximately 10 and 35 % at 30% moisture meet the safety requirements from the RAAP hazard analysis and are within the overall composting parameters included in the BAAP composting study.[8]

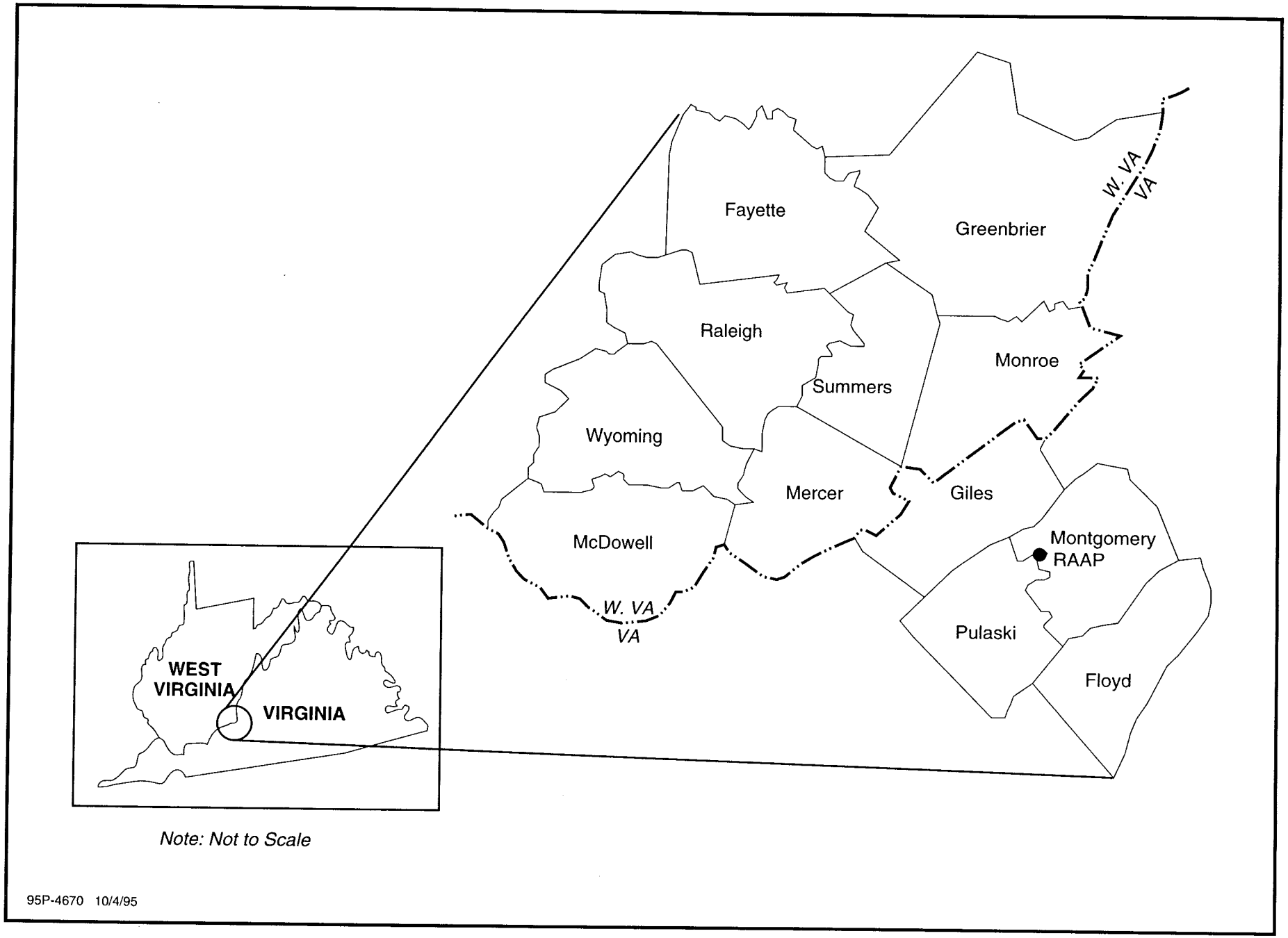


FIGURE 1-1 LOCATION OF RAAP IN VIRGINIA

Based on these positive findings, a conceptual level analysis of the use of composting technology for the treatment of NC fines was conducted. The composting process is anticipated to yield a nonreactive soil amendment suitable for beneficial uses. NC fines loading rates and treatment periods were based on previous composting studies[8] and the hazard analysis conducted by RAAP. The loadings indicated by the RAAP hazards analysis to be nonreactive at moisture levels acceptable for composting were used in the conceptual level development and cost analysis. Using a NC fines throughput of 1,250 lb/day (dry basis) and a 35% NC fines loading at 30% moisture, the total 20-year project cost, including contingency, was estimated to be $6,532,000. This corresponds to a cost of $1,000/ton of NC fines, or $310/yd^3 of NC fines.

1.4 OBJECTIVES

The overall objective of this Task Order is to prepare a report summarizing the regulatory requirements associated with composted NC fines disposal and evaluating the feasibility, including costs, of various end-use options. End-use options to be considered include the following:

- Land application (with crop harvesting) by the installation.
- Providing local farmers with compost as a soil amendment.
- Land application for reclaiming lands disturbed by mining.
- Landfilling the finished NC fines compost.

The following overall approach was used in conducting this evaluation:

- A site visit to RAAP was conducted on 20 March 1995. During this visit, meetings were held with RAAP personnel to discuss the NC production process. A site tour was conducted to evaluate on-site land use and availability; appropriate mapping and other information was obtained or requested. Site visit notes are provided in Appendix A.
- Potentially applicable regulatory information was obtained and reviewed. This information included federal and state (Virginia) solid waste and sewerage regulations, as appropriate.

- Projected finished compost quantities were estimated based on current NC fines production rates and presently stored quantities at RAAP and the general operating parameters for NC fines composting as established in previous projects.[7,8,12]

- A conceptual evaluation of each disposal option was conducted, considering compost quantities, regulatory analyses and local conditions. Location-specific information was used in conjunction with the estimated compost chemical composition and regulatory constraints to determine appropriate compost application rates for each end-use option. Land acreage requirements and subsequent costs associated with each option were calculated.

Since any evaluation of these options will be to some extent location-specific, two test cases were selected for this evaluation: (1) Badger AAP in Baraboo (BAAP), Wisconsin, which historically produced nitrocellulose; and (2) Radford AAP in Radford, Virginia, which currently produces nitrocellulose. This report addresses RAAP, whereas the analysis of compost disposal for BAAP is presented in a separate document.

SECTION 2
COMPOST DISPOSAL OPTIONS SELECTION CRITERIA

Previous work has shown that composting of NC in soils is technically achievable.[7,8] Recently, an economic analysis has shown that composting of NC fines is an economically feasible treatment alternative.[12] The composting process will yield a beneficial soil amendment that will be available for various end-uses.

This section describes the criteria used in selecting potential sites for various management options. The criteria present possible regulatory and engineering limitations investigated to determine the feasibility of using available land for compost application.

2.1 INSTALLATION LAND APPLICATION

In this alternative, RAAP will use the compost, as a beneficial soil amendment, on available agricultural land at the installation. The nitrogen-rich compost will be applied to land used for agricultural purposes. The crops planted on these sites will be harvested to prevent nitrogen accumulation in the soil and potential migration into groundwater. This option will require the installation to initiate and maintain a full-scale farming operation. The farming operation will consist of activities such as plowing, seeding, tilling, applying the compost, and harvesting the vegetation. The harvested vegetation would be given away at no cost or income to the installation.

The feasibility and acceptability of the land application is directly determined by the characteristics of the material to be applied and the characteristics of the land in the application area. A preliminary evaluation of the availability of suitable land within the RAAP facility was conducted.

The following criteria were used in delineating land within the installation that is potentially suitable for compost land application with subsequent crop harvesting:

- Federal and state regulatory constraints on application rates based on compost chemical constituents were used in conjunction with crop uptake data and estimated finished compost quantities (450 tons/year) established in the *Composting of Nitrocellulose Fines - Hazards Analysis* [12] to determine the required acreage for land application. Calculations are presented in Appendix D.

- Current land uses were determined from information supplied by RAAP.

- Potentially available acreage was approximated from RAAP area maps.

- Slope requirements for land application was determined from federal and state regulations where possible.

- Slopes of potentially available land were determined from topographical maps.

- Applicable buffer zones for application areas were determined from federal and state regulations.

- Hauling distances and spreading/harvesting costs were approximated based on available information.

2.2 SUPPLY OF COMPOST FOR AGRICULTURAL LAND APPLICATION

In this alternative, the compost will be applied to off-site locations or at the installation on land leased by the local farmers. The installation will transport the finished compost to the farmer's location of application, at no cost to the farmer. The farmers will use the compost as a beneficial soil amendment to be applied to the land as a nitrogen source for vegetation. The farmers will incur all farming operations costs. Application to on-site land by local farmers would be preferable to off-site farm sites because the installation could more easily monitor the area of application for nitrogen accumulation in the soil and potential migration to groundwater.

The following criteria were used in delineating land in the vicinity of RAAP, which is potentially suitable for land application to farming areas as a soil amendment:

- Federal and state regulatory constraints on application rates based on compost chemical constituents were used in conjunction with crop uptake data and estimated finished compost quantities (450 tons/year) established in the *Composting of*

Nitrocellulose Fines - Hazards Analysis,[12] to determine the required acreage for farming land application.

- Areas currently being used for agricultural purposes were determined from local land use maps.
- Prevalent agricultural crops for the RAAP vicinity were determined from agricultural agencies in the vicinity of RAAP.
- Potentially available acreage was determined from local land use maps.
- Slope requirements for land application were determined from federal and state regulations.
- Slopes of potentially available land were determined from topographical maps.
- Applicable buffer zones for application areas were determined from federal and state regulations.
- Hauling distances were approximated based on information from local land use maps.

2.3 MINING RECLAMATION LAND APPLICATION

In this alternative, the compost will be supplied to surface mine facilities for use as a soil amendment for reclaiming strip mines. RAAP will transport the finished compost to the surface mine, at no cost to the mining company. The mining company will utilize the compost as a beneficial soil amendment. The mining company will incur all operations costs.

The following criteria were used in delineating land, which is potentially suitable for compost land application for the purpose of mining reclamation:

- Federal and West Virginia state regulatory constraints on application rates based on compost chemical constituents were used to determine the required acreage for mining reclamation to dispose of the 450 tons of finished materials annually.
- Areas currently being strip mined were determined from West Virginia strip mine permitting information.
- Application requirements were determined from federal and state regulations.

- Hauling distances were approximated from topographical maps.

2.4 LANDFILLING

Landfilling of the finished compost may be necessary because of a lack of demand by local farmers for the compost or the inability of the installation to apply it on-site. In this alternative, the finished compost would be deposited in a landfill for final disposal. This alternative would not take advantage of the possible beneficial use of the compost as a soil amendment.

The following criteria were used in evaluating landfilling as a disposal option for NC fines compost:

- The applicability of landfilling finished compost was determined by federal and state regulations.
- Hauling distances was approximated from topographical maps.

SECTION 3
REGULATORY SUMMARY

3.1 INTRODUCTION

A federal and state regulatory review was conducted to determine issues that may impact management and disposal options for NC compost. Hazardous and solid waste regulations were examined with respect to specific applications of the finished compost.

3.2 REGULATORY STATUS OF FINISHED NC COMPOST

The U.S. Army discharges wastewater from the production of NC at RAAP to its on-site treatment plant in compliance with the Clean Water Act of 1977 and Federal Pretreatment Regulation for Existing and New Sources of Pollution (40 CFR 414). The NC fines settle out of the wastewater and are stored under water in tanks. The U.S. Army does not consider the NC fines to be a waste, but rather, a recoverable and reusable material.

It will be necessary to determine the potential status of NC fines as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) Subtitle C in order to evaluate management options for the compost. As discussed in subsequent sections, various management options, including land application, may require certification that the material being managed or applied is not a hazardous waste. If they were considered hazardous wastes, a key distinction would be that between listed (K, F, P, or U) wastes and characteristic wastes (D). If the NC fines were listed wastes, their subsequent treatment, disposal, or other management would have to meet hazardous waste management requirements, or the material would have to be specifically delisted. If the materials are RCRA characteristic wastes, they would have to be treated such that they no longer exhibit the RCRA characteristic, at which point they could be managed as nonhazardous wastes.

Based on information developed in this project, NC fines at RAAP are not considered to be RCRA Subtitle C hazardous wastes. EPA has made the determination that nitrocellulose does not pose a

toxicity hazard that warrants regulation as summarized in the Nitrocellulose Health Advisory document.[5]

Although EPA's original Listing Background Document, Explosives Industry[16] indicates that sludges from explosives manufacturing and processing may be listed on the basis of reactivity, the Army has successfully agreed that NC fines are not listed wastes.[17] As noted previously, the Army does not, in fact, consider these materials to be wastes in their present form.

Although NC fines are not considered to be a waste by the Army, future management options that will result in their being disposed of as a waste (such as landfilling) may need to consider their classification as RCRA characteristic wastes.

NC fines do not exhibit the RCRA characteristics of ignitability, corrosivity, or toxicity. Although NC fines can be reactive under specific conditions, particularly when dry, the finished compost mixtures will not be reactive since adequate moisture will be provided and the NC fines will have been treated to levels determined to be nonreactive in the RAAP Hazards Analysis. In particular, final NC concentrations will conservatively be less than 10% NC.[12] Results of the RAAP testing indicated that at concentrations less than 12% NC, NC fines compost was nonreactive at all moisture levels. Results of the RAAP Hazards Analysis were summarized in the *Composting of Nitrocellulose Fines-Hazards Analysis* report .[12]

The finished compost materials, which are a mixture of residual NC fines and amendments, may be considered a solid waste as federal regulations (40 CFR261.2) state that a solid waste is any recycled material that is "used to produce products that are applied to or placed on the land or are otherwise contained in products that are applied to or placed on the land..." . With this in mind, it may be necessary to demonstrate that the finished NC compost is not hazardous and does not exhibit the RCRA characteristic of reactivity prior to placement on land as a solid waste. Federal regulations describe the properties of solid wastes that exhibit this characteristic in 40 CFR 261.23. These properties include:

- Normally unstable and readily undergoes violent change without detonating.
- Reacts violently with water.
- Forms potentially explosive mixtures with water.
- When mixed with water, generates toxic gases, vapors, or fumes in a quantity sufficient to present danger to human health or the environment.
- Is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.
- Is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.
- Is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.
- Is a forbidden explosive as defined in 49 CFR 173.51; or a Class A explosive, as defined in 49 CFR 173.53; or a Class B explosive, as defined in 49 CFR 173.88.

There are no prescribed analytical methods in the federal or state regulations to determine whether a waste has these reactive properties; however, laboratory tests can be designed to demonstrate their presence or absence. Therefore, such laboratory-designed tests can be used to verify that the final NC compost mixture is not reactive and can be disposed as a nonhazardous solid waste. Reactivity tests, which are commonly used include Critical Diameter, Bureau of Mines (BOM) Zero Gap, and Deflagration to Detonation Transition (DDT). Therefore, it is assumed for this project that NC fines compost will not be a RCRA listed or RCRA characteristic waste.

Review and comparison of the state and federal regulations indicates that their criteria for identifying hazardous wastes are equivalent. Therefore, a solid waste considered nonhazardous under the federal regulations would be considered the same under the Commonwealth of Virginia regulations. Since it is expected that the finished compost will be considered a nonhazardous solid waste under the federal regulations, it is also expected to be considered the same under the state regulations. The following subsections contain a discussion of applicable or potentially applicable regulations for the land

application or landfilling of finished NC compost in Virginia and reclamation of mined land using finished NC compost in West Virginia.

3.3 VIRGINIA REGULATIONS

3.3.1 Disposal of Finished NC Compost in a Sanitary Landfill

The Commonwealth of Virginia solid waste regulations state that "Solid waste disposal facilities shall be maintained and operated in accordance with the permit issued pursuant to these regulations, and in accordance with the approved design and intended use of the facility," (VR-672-20-10 Part V, 5.0 B). In VR-672-20-10 Part V, 5.1(16), it is also stated that sanitary landfills may receive compost.

Compost is defined in VR-672-20-10 Part I, as "a stabilized organic product produced by a controlled aerobic decomposition process in such a manner that the product can be handled, stored, and/or applied to the land without adversely affecting public health or the environment." Since it is expected that the finished NC compost can be considered in this category, placement in a sanitary landfill can be a viable disposal option in the Commonwealth of Virginia.

3.3.2 Land Application of Finished NC Compost

The Commonwealth of Virginia does not have specific regulations that address land application of solid waste other than sewage sludge. In the absence of other regulations, the Virginia sewerage regulations are considered for land application of finished NC compost. Although in some instances the following discussion references finished NC compost, "sludge" is referenced in the regulations.

Prior to operating a land spreading facility, a sludge (compost) Management Plan for the finished NC compost must be submitted to and approved by the State Water Control Board, State Department of Health, and State Department of Agriculture and Consumer Services. The Management Plan shall include sludge (compost) characterization, description of facility and soil characteristics, description of agricultural practices and pertinent calculations justifying storage and land area requirements. A written

agreement will be required between the sludge (compost) applicator and the land owner. This agreement will indicate the terms and conditions of sludge (compost) application.

An Operation Plan is required for submittal prior to commencement of land spreading operations. It will specify the proposed site management practices including cropping restrictions and access controls. Additionally, land owners within 200 feet (for frequent use) of the proposed facility must be notified of the intended land application activities.

The sludge (finished compost) materials must meet the following regulatory criteria to be acceptable for land application:

- The sludge (compost) must be certified not to be a hazardous waste.
- The sludge (compost) must meet allowable concentration limits for heavy metals. These limits are provided in Table B-1 in Appendix B.

For sewage sludge, biological and/or chemical stabilization is also required due to the potential for pathogen transfer from the sludge. However, this requirement should not be applicable to the finished NC compost materials since they will be pathogen-free.

According to VR 355-17-112.02, "Agricultural use of sewage is the land application of Biosolids to cropland or pasture land to obtain agronomic benefits as a plant nutrient source and soil conditioner. This use shall require a system design which ensures that the land application procedures are performed in accordance with sound agronomic principles." The finished NC compost will serve as a soil conditioner and plant nutrient source for the intended crop to be harvested.

The regulations indicate that the operation of a land application facility can not result in a hazard to public health, wildlife, water quality, or other environmental resource. In addition, the agricultural use of the sludge (finished NC compost) can not result in harm to threatened or endangered species of plant, fish, or wildlife, nor result in the destruction or adverse modification of the critical habitat of a threatened or endangered species.

Regulation VR 355-17-112.02 states that the following site conditions must be met:

- Depth to bedrock or restrictive layers should be a minimum of 18 inches.
- pH of the sludge (compost)/soil mixture may be required to be 6.0 or greater at the time of each application if the sludge (compost) cadmium concentration is greater than or equal to 21 mg/kg.
- Sludge (finished NC compost) shall not be applied to site slopes exceeding 15%.

The location of land application of sludge (finished NC compost) shall not occur within the following minimum buffer zone requirements (VR 355-17-112.02):

- Occupied dwelling(s) - 200 feet.
- Water supply wells or springs - 100 feet.
- Property lines - 100 feet.
- Perennial streams and other surface waters - 50 feet.
- Intermittent stream/drainage ditches - 25 feet.
- All improved roadways - 25 feet.
- Rock outcrops and sinkholes - 25 feet.
- Agricultural drainage ditches with sloped equal to or less than 2% - 10 feet.

In accordance with sound agronomic principles, applied nutrients, such as phosphorus, potassium, and particularly nitrogen, must not exceed crop requirements so that contamination of surface and groundwater does not occur. Specifically, process design considerations shall include sludge (compost) composition, soil characteristics, climate, vegetation, cropping practices and other pertinent factors in determining application rates. Site-specific application rates should be proposed using pertinent sludge (compost) plant available nitrogen (PAN) and crop nutrient needs, the annual pollutant loadings and cumulative metals loading rates (Table A-2), and the maximum calcium carbonate equivalent (CCE) loading rates (Table A-3). Groundwater and surface water monitoring may be required if the commissioner determines that a potential environmental or public health concern exists.

In summary, the Commonwealth of Virginia has not promulgated specific regulations concerning the land application of solid wastes, such as compost materials. Regulations concerning the land application of sewage sludge may not be directly applicable but may be relevant requirements when considering land application of finished NC compost.

3.3.3 Use of Finished NC Compost for Surface Mined Land Reclamation

In addition to land disposal and land application, reclamation of surface mined land was also considered as a potential end use for the finished NC compost generated at RAAP. It was found that the neighboring state of West Virginia contained a number of sites that may require reclamation to restore vegetation to land disturbed by mining operations. Because of the number and proximity of potential reclamation sites to RAAP, the State of West Virginia regulations were reviewed to determine the viability of this option.

According to the West Virginia Office of Surface Mining and Reclamation, before a solid waste is applied to surface mined land, it must be demonstrated that the waste is not hazardous. Also, it needs to be demonstrated that the use of the waste will be beneficial in the reclamation of the land. These requirements will apply to the finished NC compost. Finally, either the Revegetation Plan contained in the original approved surface mine permit application needs to be revised or a new separate revegetation permit application needs to be prepared for the use of finished NC compost and approved by the Office of Surface Mining Reclamation.

Like the Commonwealth of Virginia, the State of West Virginia does not have specific regulations that address land application of solid waste other than sludge. In the absence of other regulations, the West Virginia Sewage Sludge Management Regulations are considered for the finished NC compost. Although in some instances, the following discussion references finished NC compost, "sludge" is referenced in the regulations.

The following restrictions have been placed on siting land application facilities (47 CSR 38D-3.2) such that the sludge (finished NC compost) cannot be applied to:

- Land that is frozen, snow-covered, or known to be flooded on a regular basis.
- Land within 50 feet of surface water.
- Land within 200 feet of a drinking water supply.
- Land within 200 feet of an occupied dwelling.
- Land within 50 feet of a federal or state highway.
- Land within 100 feet of an adjacent property owner's property line.
- Land on which drainage leads into a sinkhole.
- Land that has been tested and determined to have a pH of less than 6.2, unless the pH is adjusted to 6.2 or greater.
- Land that has a slope greater than 15%.
- Land that has a seasonal high groundwater table less than 2 feet from the surface.
- Land that has less than 6 inches of soil over bedrock or impervious pan.
- Land containing soil with surface permeability of less than 0.6 inches/hour or greater than 6 inches/hour.
- Land within the 100-year floodplain unless provisions have been made to prevent encroachment of flood waters.

The following restrictions concerning land application rates are contained in 47 CSR 38D-3.2:

The sludge (compost) cannot be applied in a manner that will result in exceeding the maximum soil concentrations for the metals listed in Table C-3 in Appendix C.

- The Director shall assign an individual and lifetime loading rate for each land application site by considering background soil concentrations and maximum allowable pollutant concentrations as per Table C-1 and Table C-3 in Appendix C of this report.
- If circumstances at the land application facility result in short-term excursions of Table C-1 criteria, the Director may develop temporary loading rates based on the provisional limitations of Table C-2 in Appendix C.

- No land ... shall be allowed to accept or store so much sludge (finished NC compost) as to exceed the agronomic rate or a rate of 15 dry tons per acre per year, whichever is less: provided, up to 25 dry tons per acre per year may be applied in the reclamation of surface mined land.

- Sludge (compost) cannot be stored at the site for a period of longer than 1 week unless provisions have been made to prevent leachate runoff into surface or groundwater.

A land application permit must first be obtained before land application of the sludge (finished NC compost) can proceed. The general permit application must provide information including the location of the facility; a description of activities to be conducted; operator identification; other environmental permits issued by any local, state, or federal agency; description of the source of the sludge (compost); amount of sludge (compost) generated; content of heavy metals, pathogens, toxins or vectors and moisture present in the sludge (compost); locations, actual amounts, and capacity of storage and land application facilities; quality of the sludge (compost); and detailed design and description of the method to collect and control leachate and surface water runoff.

Other informational requirements specific to land application include soil analysis for pH, potassium, phosphorous, nitrogen, all metals listed in Table C-1, and any other analysis requested by the Director; nitrogen content of the sludge (compost); a soils map with sites defined; an agreement among the supplier of sludge (compost), the applier, and the owner of the site; a description of future uses of the site; information relative to past applications of sludge (compost) at the site, if any; information relative to past fertilizer applications at the site; any additional chemical analyses performed; methods for land application; methods for transportation of the sludge (compost) to the site; and a description of the methods to be utilized to adjust and maintain the soil to a minimum pH of 6.2 for at least 5 years from the date of application.

In summary, the State of West Virginia has not promulgated specific regulations concerning the land application of solid wastes, such as compost materials. Regulations concerning the land application of sewage sludge may not be directly applicable but may be relevant requirements when considering land application of the finished NC compost to reclaim surface mined land.

SECTION 4
COMPOST DISPOSAL ALTERNATIVES

Several end-use alternatives for the finished NC fines compost were evaluated using the criteria discussed in Section 2. Results of this evaluation are presented in this section. End-use alternatives evaluated included:

- Land application (with crop harvesting) by the installation.
- Providing local farmers with compost as a soil amendment.
- Land application for reclaiming lands disturbed by mining.
- Landfilling the finished NC fines compost.

Federal and state regulations governing the disposal alternatives of the finished NC fines compost were described in Section 3. All of the proposed end-use alternatives may be accomplished in compliance with federal, Virginia, and West Virginia regulations, with some restrictions.

Land application of NC fines compost will provide plant nutrients for crops and will add humus to the soil. Increasing the organic content of a soil increases its ability to hold plant nutrients and moisture. An immediate benefit of compost land application is its plant nutrient content, particularly in terms of nitrogen. However, to avoid contamination of surface and groundwater, it is important that applied plant nutrients, particularly nitrogen, do not exceed crop requirements and other losses. This is true for commercial fertilizer application as well as compost application.

When NC fines compost is applied to land, the nitrogen it contains will reach some combination of the following fates:

- NH_3 volatilization to the air.
- Nitrification and leaching to groundwater as NO_3^-.
- Nitrification and denitrification, with nitrogen gas (N_2) volatilization to the air.
- Plant uptake of NH_3-N and NO_3^-.

In addition to concern for the fate of nitrogen, metals may also need to be considered during compost land application processes. Generally, regulatory loading rates for copper, nickel, and zinc are based

on the potential to decrease crop yields, particularly for leafy green vegetables. Lead loading rates are generally specified to reduce chances for direct ingestion by animals. Lead is not taken up by vegetation unless it is present at very high concentrations. Cadmium can accumulate in vegetation without causing crop damage. Therefore, cadmium loading rates are set to prevent entrance into the mammalian food chain where it could lead to kidney disorders.[14]

In general, the amount of NC fines compost that can be applied to the land is determined by constituent (i.e., various metals, phosphorus, and nitrogen) loadings. Specific constituents determining application rates are identified by individual states. As discussed in Section 3, Virginia regulations dictate levels of metals and nitrogen that may be applied to land. Virginia also requires that applied nutrients, such as phosphorus, potassium, and nitrogen, not exceed crop requirements. Significant concentrations of metals listed in Table A-1 would not typically be found in either the NC fines or the amendments used in the composting procedure. However, both the proposed amendments and NC fines are significant sources of nitrogen. Therefore, land application of the compost will probably be a nitrogen-limited process. For comparison, the mean total nitrogen in typical wastewater sludge is 3.9%.[15] The nitrogen content in NC is up to 14.14%. Prior to land application, analyses should be conducted to verify these assumptions.

Appendix D shows the equations and calculations used to estimate the amount of finished compost that can be applied per acre of land based on nitrogen limitation. These calculations were based on producing approximately 450 tons/year of finished compost (on a dry basis). This compost production rate allows for treatment of the approximately 1,250 lb/day of NC fines (dry basis) being produced at RAAP. This production rate would require a facility of the same size as that described in the *Composting of Nitrocellulose Fines - Hazards Analysis* report.[12] The following assumptions were used for the calculations of land requirements:

- All the nitrogen contributed by the NC fines is nitrate-nitrogen (NO_3-N).
- All the nitrogen contributed by the amendments is ammonia-nitrogen (NH_4-N).

- A volatilization factor of 0.5 was applied to ammonia because of the surface-applied method of application. This means that one-half of the ammonia present in the finished compost will be volatilized during land application.

- No organic nitrogen exists in the final compost.

- The annual nitrogen uptake by vegetation was 210 lb/acre (based on Kentucky Bluegrass, chosen because its nitrogen uptake rate is near the average for grass species). Actual nitrogen uptake will vary depending on the vegetation.

- Vegetation will be harvested annually from the application area (except with the mining reclamation alternative).

The amount of nitrogen that can be applied to the land will depend in large part on the nitrogen uptake rate of the vegetation to be planted. The net amount of nitrogen (after volatilization) that is applied to the land should equal the amount of nitrogen taken up by the vegetation and subsequently removed from the land through harvesting. If the crop is not harvested, the nitrogen from the vegetation would return to the soil. The land area needed for compost application is, therefore, calculated by setting the nitrogen losses by all mechanisms, which includes the vegetation's annual nitrogen uptake rate, equal to the amount of nitrogen to be applied to prevent a net nitrogen accumulation in the soil. Application of nitrogen in excess of that which can be removed by volatilization and plant uptake will be available for leaching to groundwater, generally as nitrate nitrogen. NO_3-N is regulated in drinking water under the Safe Drinking Water Act (SDWA) with a maximum contaminant level (MCL) of 10 mg/L NO_3-N. Many agencies restrict NO_3-N in the percolation from application areas to the SDWA MCL of 10 mg/L.

As given in Appendix D, the amount of compost that could be applied annually at the specified nitrogen uptake rate is estimated to be 1.4 tons of compost/acre. Based on this application rate of 1.4 tons/acre, approximately 320 acres/year will be required for final compost disposal. As stated previously, the number of acres will vary based on the vegetation assumed to be grown. For example, alfalfa has a nitrogen uptake value of up to 600 lb/acre compared with the specified rate of 210 lb/acre for Kentucky Bluegrass. Therefore, if alfalfa is planted instead of Kentucky Bluegrass, more nitrogen will be utilized by the vegetation and more compost may be applied per acre. End-use alternatives for this compost are discussed in the following subsections.

4.1 LAND APPLICATION BY THE INSTALLATION

Land application of the NC fines compost as a possible end-use alternative would be acceptable under the Virginia regulations but would require permitting and would be subject to restrictions. As discussed in Subsection 3.2.2, land application would require a Management Plan and an Operations Plan to be submitted to the State Water Control Board, State Department of Health, and State Department of Agriculture and Consumer Services for written approval prior to commencement of compost application operations. Without the written approval of the plans from the mentioned departments, land application would not be permitted and the NC fines compost would then be landfilled. Certain restrictions would also apply to land application, as outlined in Subsection 3.2.2.

Land application of the finished NC fines compost at the installation would consist of application of the compost and the planting and harvesting of vegetation to remove the nitrogen contributed by the compost from the site. The type of vegetation to plant would be influenced by the following factors:

- Vegetation suitable for the particular climatic region and soil specifications.
- The rate of nitrogen uptake of the vegetation to be planted.
- Maintenance of the land to promote growth of the vegetation.

Planting and harvesting would have to be conducted annually to prevent a net nitrogen accumulation in the soil.

Available land within the installation's control was identified through land usage maps of the installation. Topography of the area was also taken into account to ensure the slope does not exceed 15% as required by Virginia state regulations. Topography was also investigated to ensure that the compost application equipment can be safely operated at the slopes present on the specified land and that runoff and erosion can be minimized to prevent nitrogen contamination of surface water. The installation has no available land at the Radford location, but does have available land at its New River Ordnance Plant, located approximately 10 miles southwest of the Radford installation, next to Dublin, Virginia. The land at the New River Ordnance Plant is currently being leased out to farmers; therefore, this land is already conditioned for crop production. The installation has approximately 205 acres of

grazing land and 405 acres of crop land. This acreage is in excess of the land requirements calculated in Appendix D. Although all this land may not be available for use because of various structures and roads within the area, it seems likely that the required 320 acres will be available.

The costs associated with this disposal alternative would include:

- Costs and fees associated with the preparation and submittal of a Management and Operations Plan to the appropriate departments for approval.
- Transportation of the finished NC fines compost to the New River Ordnance Plant.
- Purchase or lease of equipment necessary for application of the compost and for the planting and harvesting of the vegetation.

4.2 PROVIDING LOCAL FARMERS WITH COMPOST AS A SOIL AMENDMENT

According to Virginia regulations, the finished NC fines compost could be used by local farmers as a nitrogen source for crop growth for animal or human consumption if the crops meet all applicable contaminant levels as established by the U.S. Food and Drug Administration. The compost could also be supplied to local municipalities or counties for use in recreation areas. The same vegetation constraints would exist for application by local farmers that exist for application of compost on the installation. As calculated in Appendix D, a total of 320 acres/year will be required for land application.

The amount of land currently being used for agricultural purposes within the counties surrounding the installation was identified through area land usage maps in conjunction with topography maps. The installation in located in Montgomery County. Counties in proximity to the installation include Giles, Floyd, and Pulaski. These counties, together with Montgomery County, make up what is known as the New River Valley District. Land was identified that is currently used for agricultural purposes and also meets slope criteria. Land appropriate for usage is identified in Figure 4-1 for Montgomery County and Figure 4-2 for Giles Counties. Information concerning Pulaski County is unavailable and information for Floyd County was limited. Approximately 7,000 acres are available in Montgomery

and Giles Counties alone. Therefore, acreage in excess of the land requirements calculated in Appendix D exits in the vicinity of the installation. Based on the large amount of available agricultural land in the vicinity of RAAP, it seems likely that the required acreage could be obtained. Approximately 90% of the agricultural land identified in the vicinity is located within 20 miles of the installation.

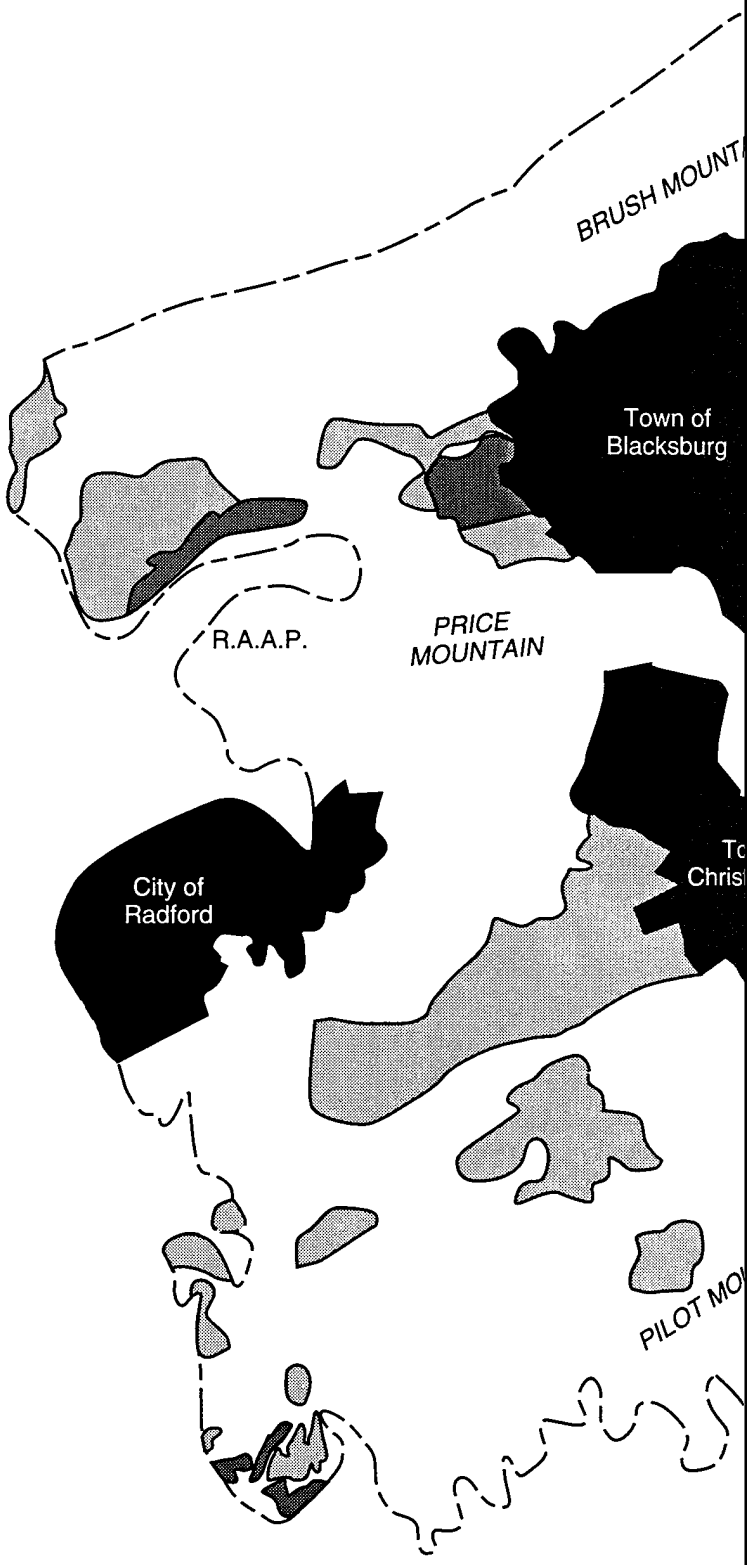
The constraints associated with land application of the compost at the installation also apply to local farmers. According to Virginia regulations governing land application of sewage sludge, the installation and the farmers using the finished NC fines compost would be required to enter into an agreement concerning annual monitoring of the land on which the compost would be applied. The installation would bear the responsibility for fulfilling all monitoring requirements.

The costs associated with this end-use alternative would include:

- Transportation of the finished NC fines compost from the installation to the farmers.
- Costs and fees associated with the preparation and submittal of a Management and Operations Plan to the appropriate departments for approval. It is assumed that these costs and fees would be borne by the installation.

4.3 LAND APPLICATION FOR RECLAIMING LANDS DISTURBED BY MINING

The land application of the NC fines compost for mining reclamation would allow, in general, for a higher nitrogen load per acre to be applied than is possible in other land application scenarios. Thus, this would generally require less land for compost application compared with the annual application due to the anticipated higher allowable nitrogen load allowed per acre. Actual nitrogen loading rates will be evaluated on an individual basis in the required West Virginia Mining Revegetation Plan. Instead of an annual application, this alternative would probably be a one-time application. Land in excess of the required land calculated in Appendix D will be necessary because the compost will not be applied annually in the same area.



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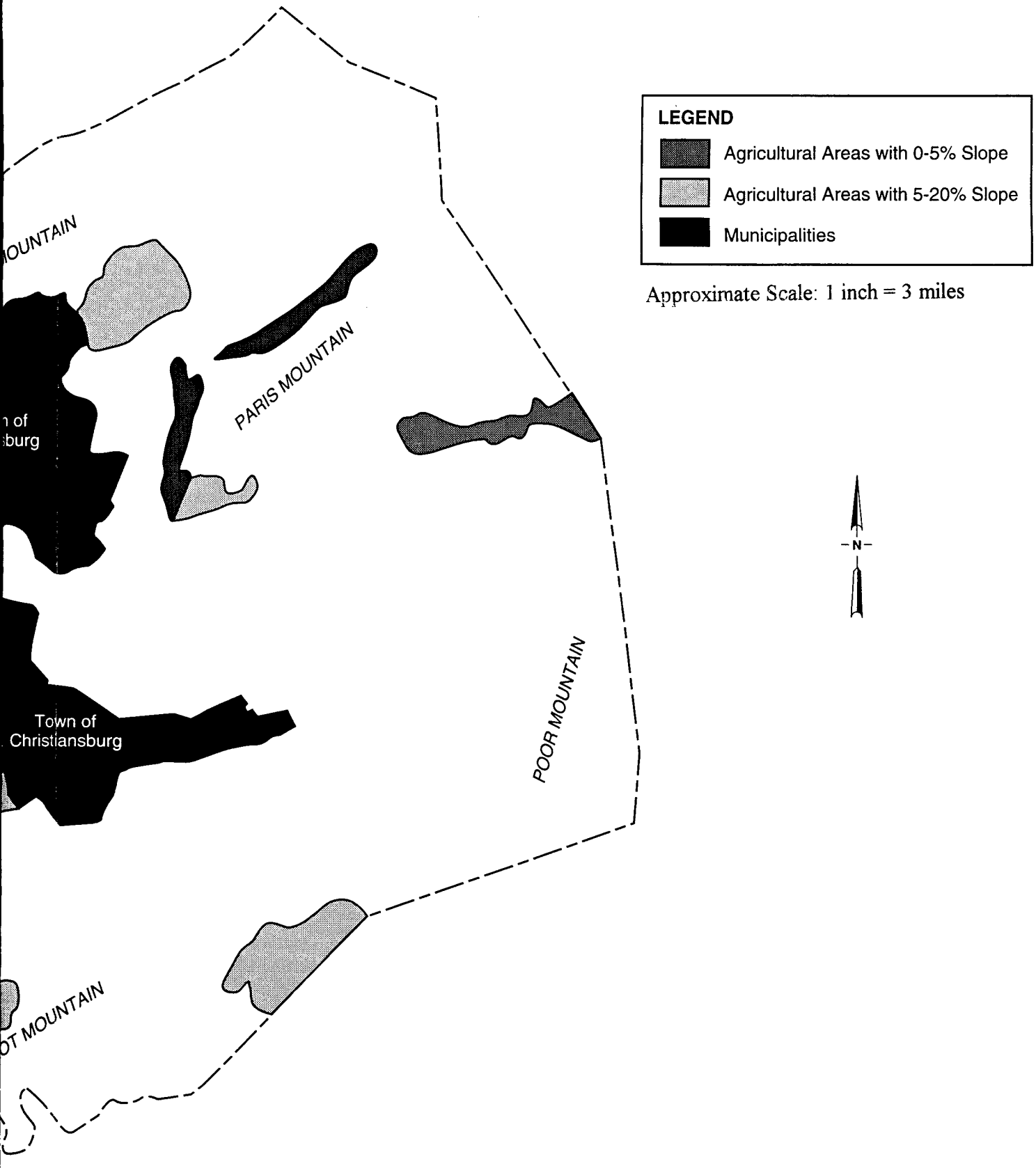

**FIGURE 4-1 LOCATION OF AGRICULTURAL
WITHIN MONTGOMERY COUNTY
IDENTIFIED FOR POSSIBLE USA**

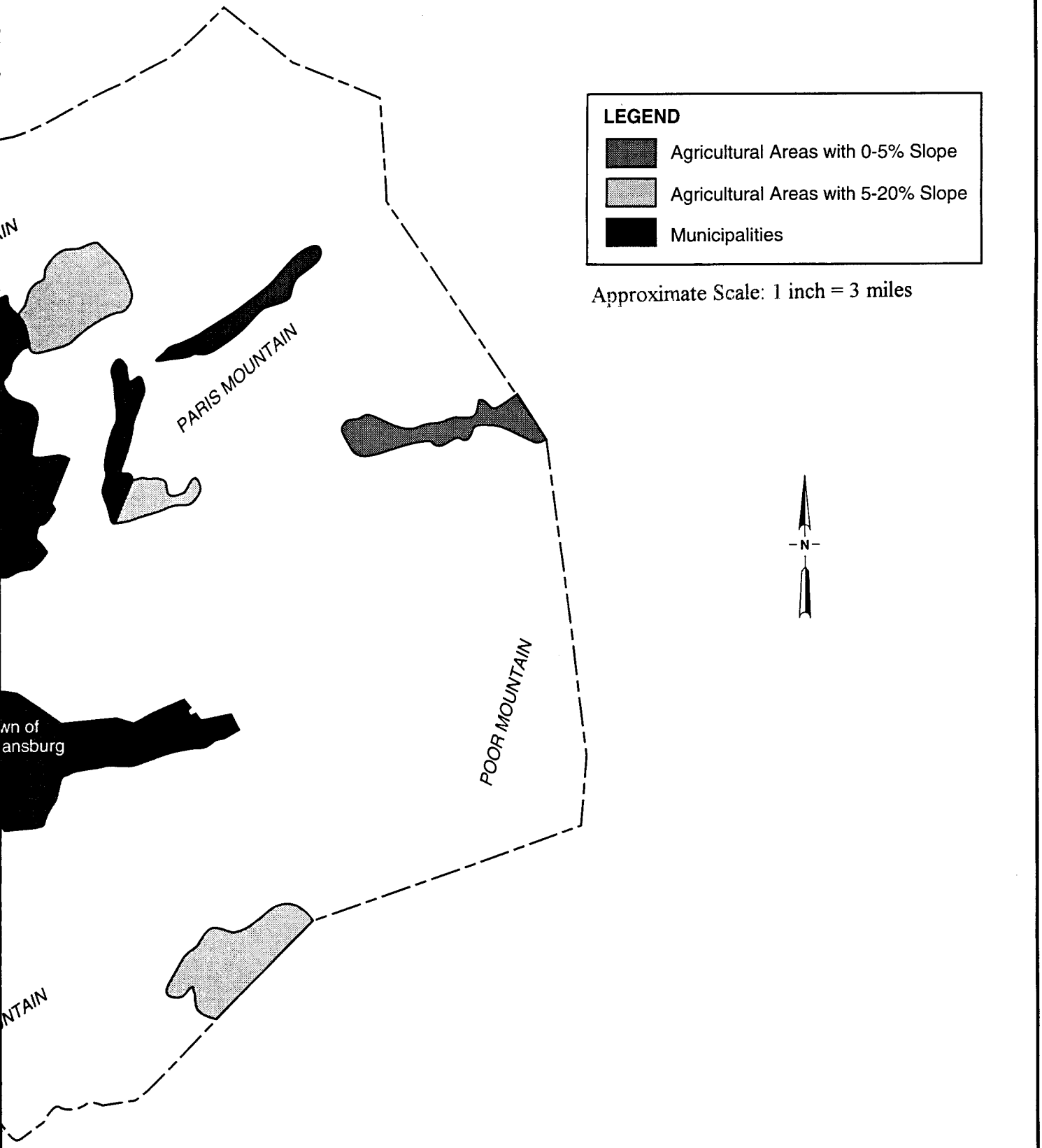

FIGURE 4-1 LOCATION OF AGRICULTURAL LAND WITHIN MONTGOMERY COUNTY, VA IDENTIFIED FOR POSSIBLE USAGE

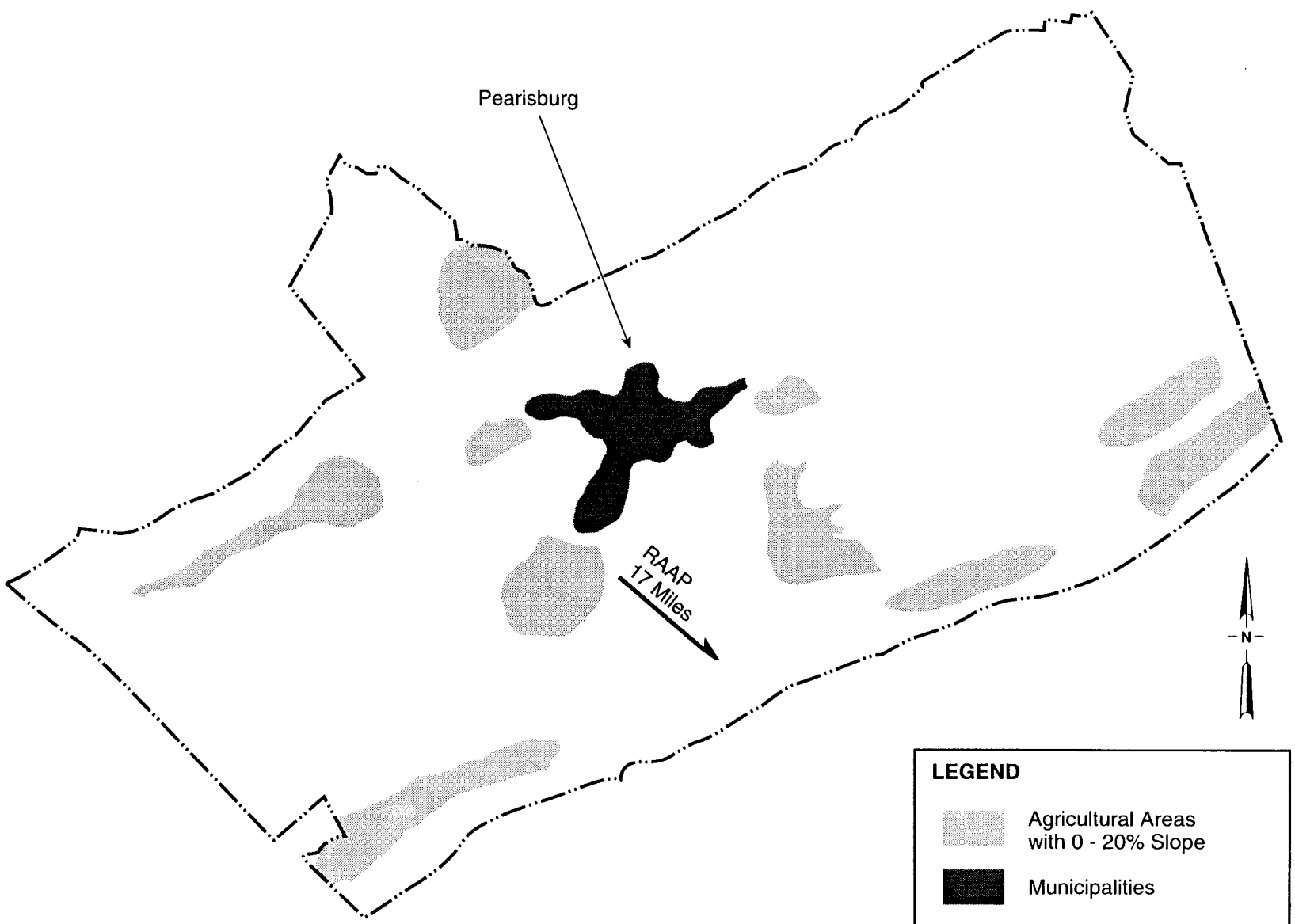

FIGURE 4-2 LOCATION OF AGRICULTURAL LAND WITHIN GILES COUNTY, VA IDENTIFIED FOR POSSIBLE USAGE

Surface mining operations in southeastern West Virginia were investigated. Conservatively, the 320 acres required for farming application were used as a basis for evaluation of available land. Surface mining operations exist in McDowell, Wyoming, Raleigh, Fayette, and Greenbrier Counties, West Virginia (Figure 1-1). The surface mines are located approximately 50 to 80 miles from the installation.

The costs associated with this end-use alternative would include:

- Transportation of the finished NC fines compost from the installation to the mining facilities to be reclaimed. The installation will incur all transportation costs.
- The mining facility would incur all operations costs.

4.4 LANDFILLING THE FINISHED NC FINES COMPOST

Landfilling of the finished NC fines compost in sanitary landfills would be an acceptable disposal alternative under the Virginia regulations. The NC fines compost would be accepted by sanitary landfills if it meets the definition of compost as described in Subsection 3.2.1. The compost may also be accepted by local composting facilities. Landfilling finished compost would be less desirable than the previously discussed alternatives because the potential benefits of the NC fines compost would not be realized. However, it may be possible to supply compost to landfills as a cover material for capped areas. This would represent a beneficial use for the product and would eliminate the costs associated with tipping fees. The costs and restrictions conservatively included in this report are for landfill inclusion rather than for cover purposes.

The costs associated with landfill disposal would include:

- Transportation of the NC fines compost to the landfill facility.
- Landfill fees.

SECTION 5
ECONOMIC ANALYSIS

Regulatory and logistical constraints associated with implementing various end-use alternatives were described in Sections 3 and 4. In this section, potential costs associated with the specified alternatives are developed. This analysis is intended to evaluate and compare the relative costs to the installation of land application either by the RAAP installation, or by area farmers, or for land reclamation, with the costs associated with landfilling the finished compost. The following alternatives will be analyzed:

- Land application (with crop harvesting) by the installation.
- Providing local farmers with compost as a soil amendment.
- Land application for reclaiming lands disturbed by mining.
- Landfilling the finished NC fines compost.

5.1 METHODOLOGY AND ASSUMPTIONS

Costs for the specified end-use alternatives were developed using conventional construction cost-estimating procedures. Unit prices were obtained from the U.S. Army Corps of Engineers (USACE) Construction Equipment Ownership and Operation Expense Schedule, the *DataQuest Bluebook,* and prevailing wages for the Richmond, Virginia, area as presented in Table 5-1. The major items included in the cost estimate are listed below:

- Land Application Processes
  - Spreading
  - Planting
  - Cutting
  - Raking
  - Baling and Loading

Table 5-1

Unit Costs for Land Application by RAAP

Item	Cost ($)*
Transportation	0.45 /ton mile
Seeds	50/acre
Compost spreading	13.75/acre
Plant crop	10.86/acre
Cut crop	14.77/acre
Rake, two times	27.23/acre
Bale and load crop	10.30/acre

*Unit costs were obtained from the following references:

USACE Construction Equipment Ownership and Operation Expense Schedule.
DataQuest Bluebook.
The prevailing 1995 wage rates for Richmond, Virginia, were used.

Note: Costs are presented on a $/acre basis because the number of acres needed will be dependent on the type of vegetation grown on the land.

- Crop seed (land application)
- Transportation of compost and/or crop
- Landfill tipping fees

In the development of the economic analysis, the following assumptions were made:

- Costs for permitting and regulatory compliance monitoring are not included in this analysis. Although there will be costs associated with these items, they are difficult to accurately assess at this time.
- No costs or income to the installation will result from transfer of the finished compost to area farmers.
- A total of approximately 450 tons/year of finished compost, on a dry basis, will be available based on a processing rate of 1,250 lb/day of NC fines on a dry basis.[12] This conservatively assumes no mass loss during composting.
- Equipment needed to spread the compost, till, plant, and harvest crops will be leased by RAAP in the land application scenario by the installation.
- In the local farm application scenario, it is assumed that the farmer will apply the compost and plant and harvest the crops. Costs associated with these operations are not included in this alternative.
- All costs are in 1995 dollars.
- Harvested crops are assumed to be distributed to users at no cost or income to the installation through a public distribution point located at or adjacent to the RAAP installation.
- Transportation costs of finished compost and harvested crop are estimated on a loaded mile basis (cost/ton/mile).
- Unit costs associated with agricultural operations are priced on a per acre basis.

5.2 CONTINGENCY

A contingency factor (generally as a percentage of total anticipated expenditure) is conventionally added to various types of cost estimates to allow for unknown and unforseeable factors or changes that may develop. Costs in this report are presented with a 15% contingency factor.

5.3 PROJECT FINANCING

It has been assumed that funds would be obtained through government appropriations on a fiscal year basis. Therefore, no costs associated with project financing are included.

5.4 RESULTS FOR END-USE ALTERNATIVES

This subsection presents potential costs associated with each end-use alternative.

5.4.1 Land Application by the Installation

Costs associated with this alternative are:

- Costs of transporting the finished NC fines compost to the application area.
- Costs associated with compost spreading, tilling, seeding, and harvesting operations. Unit costs are calculated on a per acre basis in accordance with information available for agricultural practices. Unit costs are presented in Table 5-1. These unit costs include equipment lease and operation and maintenance as well as labor.
- No transportation costs for the harvested crop are included because it was assumed that the crop would be given away at the installation at no cost or profit to the installation.

Estimated annual costs for land application of finished NC fines compost at the installation are presented in Table 5-2. Within the previously stated constraints, the cost of this alternative is

Table 5-2

Estimated Annual Costs for Land Application by the Installation

Item	%Markup	Amount	Unit Cost	Cost ($/year)
Transportation		640 tons[a]	$0.45	$2,880
Seed		320 acres	$50.00	$16,000
Compost Spreading		320 acres	$13.75	$4,400
Seeding Crop		320 acres	$10.86	$3,480
Cut Crop		320 acres	$14.77	$4,730
Rake Crop		320 acres	$27.23	$8,715
Bale and Load Crop		320 acres	$10.30	$3,300
First Subtotal				**$43,505**
Engineering, Procurement, Administrative, and Legal	@ 15%			$6,530
Contractor Markup and Profit	@ 10%			$4,350
Second Subtotal				**$54,385**
Contingency	@ 15%			$8,160
Total				**$62,500**

[a]Calculated on a wet basis

Assumptions:

Transportation costs are presented in $/ton mile.

The compost will be transported an average of 10 miles to application site.

estimated to be $62,500/year. This corresponds to a cost of $100/ton of finished compost (wet basis) or $280/ton of original NC fines (dry basis). The cost per ton of compost is less than the cost per ton of stored NC fines because the compost unit cost includes the mass of added amendments and water and is, therefore, based on a larger mass of material. The costs are for finished compost disposition only and will be in addition to treatment costs presented in the *Composting of Nitrocellulose Fines - Hazards Analysis* report.[12]

5.4.2 Providing Local Farmers with Compost as a Soil Amendment

Costs associated with this alternative are:

- Costs of transporting the finished NC fines compost to the local farms.
- No costs are included for agricultural operations because crop disposition is assumed to be performed by the individual farmer.
- No costs are included for crop disposition because crop disposition is assumed to be handled by the individual farmer.

Estimated annual costs for supply of NC fines compost to local farmers for land application as a soil amendment are presented in Table 5-3. Within the previously stated constraints, the cost of this alternative is estimated to be $8,300/year. This corresponds to a cost of $20/ton of finished compost (wet basis) or $40/ton of original NC fines (dry basis). The cost per ton of compost is less than the cost per ton of stored NC fines because the compost unit cost includes the mass of added amendments and water and is, therefore, based on a larger mass of material. The costs are for finished compost disposition only and will be in addition to treatment costs presented in the *Composting of Nitrocellulose Fines - Hazards Analysis* report.[12]

Table 5-3

Estimated Annual Costs for Providing Compost to Local Farmers for Land Application

Item	%Markup	Amount	Unit Cost	Cost ($/year)
Transportation		640 tons[a]	$0.45	$5,760
First Subtotal				**$5,760**
Engineering, Procurement, Administrative, and Legal	@ 15%			$860
Contractor Markup and Profit	@ 10%			$580
Second Subtotal				**$7,200**
Contingency	@ 15%			$1,080
Total				**$8,300**

[a]Calculated on a wet basis

Assumptions:

Transportation costs are presented in $/ton mile.

5.4.3 Land Application for Reclaiming Lands Disturbed by Mining

Costs associated with this alternative are:

- Costs of transporting the finished NC fines compost to the surface mines.
- No costs are included for agricultural operations because they are assumed to be performed by the individual mines.

Estimated annual costs for supply of NC fines compost for land reclamation of lands disturbed by mining operations are presented in Table 5-4. Within the previously stated constraints, the cost of this alternative is estimated to be $33,100/year. This corresponds to a cost of $60/ton of finished compost (wet basis) or $150/ton of original NC fines (dry basis). The cost per ton of compost is less than the cost per ton of stored NC fines because the compost unit cost includes the mass of added amendments and water and is, therefore, based on a larger mass of material. This alternative is more costly than providing the NC compost to local farmers for use as a soil amendment because of the greater transportation distances to the surface mines. The costs are for finished compost disposition only and will be in addition to treatment costs presented in the *Composting of Nitrocellulose Fines - Hazards Analysis* report.[12]

5.4.4 Landfilling

Costs associated with this alternative are:

- Costs of transporting the NC fines compost to the landfill facility. Additional material characterization information if deemed necessary by the accepting landfill.
- Landfill tipping fees.

Estimated annual costs for landfilling NC fines compost are presented in Table 5-5. Within the previously stated constraints, the cost of this alternative is estimated to be $35,700/year. This corresponds to a cost of approximately $55/ton of finished compost (wet basis) or $160/ton of original NC fines (dry basis). The cost per ton of compost is less than the cost per ton of stored

Table 5-4

Estimated Annual Costs for Providing Compost to Reclaim Land Distributed by Mining Operations in Southeast West Virginia

Item	%Markup	Amount	Unit Cost	Cost ($/year)
Transportation		640 tons[a]	$0.45	$23,040
First Subtotal				**$23,040**
Engineering, Procurement, Administrative, and Legal	@ 15%			$3,460
Contractor Markup and Profit	@ 10%			$2,300
Second Subtotal				**$28,800**
Contingency	@ 15%			$4,320
Total				**$33,100**

[a]Calculated on a wet basis

Assumptions:

Transportation costs are presented in $/ton mile.

Table 5-5

Estimated Annual Costs for Compost Landfilling

Item	%Markup	Amount	Unit Cost	Cost ($/year)
Transportation		640 tons[a]	$0.45	$2,450
Landfill Tipping Fees		640 tons[a]	$35.00	$22,400
First Subtotal				**$24,850**
Engineering, Procurement, Administrative, and Legal	@ 15%			$3,730
Contractor Markup and Profit	@ 10%			$2,490
Second Subtotal				**$31,070**
Contingency	@ 15%			$4,660
Total				**$35,700**

[a]Calculated on a wet basis

Assumptions:

Transportation costs are presented in $/ton mile.

NC fines because the compost unit cost includes the mass of added amendments and water and is, therefore, based on a larger mass of material. This alternative does not represent a beneficial use of the finished compost. This alternative is more costly than providing the NC compost to local farmers for use as a soil amendment because of the greater transportation distances to landfills from RAAP and tipping fees associated with landfilling. It was assumed that compost would be supplied to area farmers and that the farmers would pay for spreading, planting, and harvesting crops. The costs are for finished compost disposition only and will be in addition to treatment costs presented in the *Composting of Nitrocellulose Fines - Hazards Analysis* report.[12]

5.5 ECONOMIC COMPARISON OF ALTERNATIVES

The estimated annual costs for the four specified end-use alternatives are listed in Table 5-6. The most attractive alternative, based on economic considerations, is supply of the finished compost to local farms for use as a soil amendment. This alternative costs significantly less than compost application by the installation because it was assumed that the farmers will bear the costs of compost application, tilling, seeding, and crop harvesting. Land application at the installation may, however, be preferable because the installation will maintain control of the process. Land application for surface mine reclamation is a beneficial use of the material, but the transportation distance of 80 to 100 miles as compared with approximately 20 miles for provision to local farmers makes it a more costly alternative. However, it is less costly than land application by the installation. Landfilling is also less costly than application by the installation; however, it may not be a desirable alternative because there is no beneficial use gained from the composted material.

Table 5-6

Annual Cost Summary of End-Use Alternatives for NC Fines Compost

Alternative	Estimated Annual Cost ($/year)	Estimated Cost per Ton of Finished Compost ($/ton)[a]	Estimated Cost per Ton of Original NC Fines ($/ton)[b]
Land application by the installation	$62,500	$100	$280
Supply to local farmers for land application	$8,300	$20	$40
Compost to reclaim land disturbed by mining operations	$33,100	$60	$150
Compost landfilling	$35,700	$55	$160

[a]Based on 640 tons/year of compost, wet basis.
[b]Based on 225 tons/year of NC fines, dry basis.

SECTION 6
CONCLUSIONS

Previous work conducted by USAEC has demonstrated that soils containing NC can be treated effectively by composting.[7,8] Recently, it has been shown that NC fines composting may be economically feasible.[12] Composting of NC fines will produce a beneficial soil amendment.

The objective of this report is to summarize the regulatory requirements associated with various end-use options for the finished NC compost produced at RAAP and evaluate the technical and economic feasibility of these options. The end-use options that were considered include:

- Land application (with crop harvesting) by the installation.
- Providing local farmers with compost as a soil amendment.
- Land application for reclaiming lands disturbed by mining.
- Landfilling the finished NC fines compost.

All of the alternatives were found to be feasible from a logistical and regulatory perspective. Sections 2 and 3 of this report provided a description of logistical and regulatory constraints for the potential end-use scenarios. In Section 4, these constraints were applied for each scenario to determine the technical feasibility of each alternative. Economic feasibility was considered in Section 5. A basis of 450 tons/year of NC compost production, on a dry basis, was used. This corresponds to approximately 640 tons/year of compost on a wet basis. This production rate is based on the current NC fines production rate at RAAP.[12] Within the constraints described in Section 4, the annual costs were estimated for each end-use option, as shown in Table 6-1.

Based on the information developed in this report, the following steps should be taken if one of the end-use options for NC compost described is to be implemented:

- Specific sites meeting the technical and regulatory criteria discussed in Section 4 should be selected. For provision of finished NC compost to local farmers, owners need to be contacted and their willingness to participate in a land application program established.

Table 6-1

Annual Cost Summary of End-Use Alternatives for NC Fines Compost

Alternative	Estimated Annual Cost ($/year)	Estimated Cost per Ton of Finished Compost ($/ton)[a]	Estimated Cost per Ton of Original NC Fines ($/ton)[b]
Land application by the installation	$62,500	$100	$280
Providing local farmers with compost as a soil amendment	$8,300	$20	$40
Land application for reclaiming land disturbed by mining	$33,100	$60	$150
Landfilling the finished NC fines compost	$35,700	$55	$160

[a] Based on 640 tons/year of compost, wet basis.

[b] Based on 225 tons/year of NC fines, dry basis.

- Buffer zones around property perimeters, waterways, and roads should be delineated for specified properties. This would allow for calculation of actual available acreages for land application of the finished NC compost.

- Actual required acreage should be calculated based on the specific crop to be grown on each selected site.

- Compost nonreactivity should be demonstrated prior to implementation of any end-use option.

- Chemical characterization of the compost would be required for the landfill alternative to establish compliance with landfill acceptance requirements. Chemical analysis of the compost would also be required for the land application alternatives to determine nitrogen and metals content to confirm the assumptions made during application rate calculations.

SECTION 7

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APPENDIX A

NOTES ON SITE VISIT TO RAAP

Notes on Site Visit to Radford Army Ammunition Plant

On March 20, 1995, Dr. William Lowe and David Kuczykowski, both of Roy F. Weston Inc., met with Dannie A. Musser, Jim Howell, Terry Lyon, Jim A. Morris, Bill Nietzold, David Yourshaw, Jerry Redder, H.M. Harvey, and Craig Elsea at the RAAP Administration Building.

The meeting started with a short video presentation and continued with a discussion on various topics. General areas of discussion during the course of the meeting included:

- Sources, quantities, and characteristics of nitrocellulose fines (NC fines). The NC fines production and handling were reviewed. RAAP has approximately 250 to 500 million pounds* of NC fines stored under water in tanks.
- Regulatory requirements.
- Local and facility land available. Available land, under the control of RAAP, exists at the New River Ordnance Plant. Land at this location is currently being leased to farmers. The New River Valley Planning District Office was identified as a possible place to receive information on the local availability of land in the surrounding counties.
- Other options for recycling NC fines.

After the meeting adjourned, Dr. Lowe and Mr. Kuczykowski were taken on a tour of the RAAP NC production and handling facilities. During the tour, possible locations for a composting facility were identified.

After departing from RAAP, Dr. Lowe and Mr. Kuczykowski went to the New River Valley Planning District Office and met with Pat Therrien, who is a Regional Recyclables Marketing Manager of the Appalachian Regional Recycling Consortium. Pat Therrien was able to supply various maps of the New River Valley, which consists of Floyd, Giles, Montgomery, and Pulaski Counties.

* This figure has subsequently been revised to 400 million pounds of stored NC fines.

APPENDIX B

EXCERPTS FROM VIRGINIA SEWERAGE REGULATIONS

Table B-1

Recommended Ceiling Pollutant Limits for the Trace Metal Content of Biosolids Acceptable for Land Application

Pollutant	Concentration (mg/kg) Dry Weight
Arsenic	75
Cadmium	85
Chromium	3,000
Copper	4,300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	32
Zinc	7,500
Cadmium/Zinc Ratio (if cadmium equals or exceeds 21 mg/kg)	1.5%

Table B-2

Maximum Cumulative Application of Biosolids Borne Metals that Can be Applied to Soils Used for Crop Protection[1]

Metal	[Kg/ha (lb/ac)]	
Arsenic[2]	41	(31)
Cadmium	21	(18)
Chromium	3,000	(2,680)
Copper	1,500	(1,340)
Lead	300	(270)
Mercury	17	(16)
Molybdenum[2]	41	(36)
Nickel	420	(375)
Selenium	32	(29)
Zinc	2,800	(2,500)

Note:

(1) Such total applications to be made on soils with the sludge/soil mixture pH adjusted to 6.0 or greater if the sludge cadmium content is greater than or equal to 21 mg/kg.

(2) The maximum cumulative application may be increased in accordance with the results of EPA recommendations at a later date.

Table B-3

Recommended Lime Application Rates Needed to Adjust Initial Soil pH to 6.5 for Lower Coastal Plains Soils

Soil Type*

Initial Soil pH	Sandy	Loamy
	Lime (tons/acre)	
4.8	3.5	4.5
5.0	3.0	3.75
5.5	1.75	2.5
6.0	1.25	1.5

Recommended Lime Application Rates Needed to Adjust Initial Soil pH to 6.8 for Middle and Upper Coastal Plains Soils

Soil Type*

Initial Soil pH	Sandy	Loamy
	Lime (tons/acre)	
4.8		
5.0	4.25	5.75
5.5	4.0	5.25
6.0	3.0	4.0
6.5	2.0	2.75

Note: * "Sandy Soils" includes those surface soils designated by VSDA-SCS soil classification as "sandy loam" or lighter in texture; "loamy" soils include those classified as having textures heavier than sandy loam.

APPENDIX C

WEST VIRGINIA REGULATIONS

Table C-1

Maximum Concentration of Metals in Sewage Sludge for Land Application

Metal	Concentration (mg/kg)
Arsenic	41
Cadmium	10
Chromium	1,000
Copper	1,000
Lead	250
Mercury	10
Molybdenum	18
Nickel	200
Selenium	36
Zinc	2,500

Table C-2

Provisional Maximum Concentration of Metals in Sewage Sludge for Procedures Not Meeting Table C-1 Criteria

Metal	Concentration (mg/kg)
Arsenic	75
Cadmium	85
Chromium	3,000
Copper	4,300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7,500

Table C-3

Maximum Allowable Soil Concentrations

Metal	Concentration (mg/kg)
Arsenic	5.7
Cadmium	1.4
Chromium	140
Copper	140
Lead	35
Mercury	2
Molybdenum	2.5
Nickel	28
Selenium	5
Zinc	350

APPENDIX D

NITROGEN APPLICATION RATE CALCULATIONS

Appendix D

Amount of Area Required for Land Application of the Final Compost Product

Compost Specifications				
Component	% Nitrogen as is	% Nitrogen dry	Dry Material (lbs/day)	Nitrogen (lbs/day)
Nitrocellulose	12.63%	14.14%	1250	176.8
Horse Manure	1.36%	2.60%	563	14.7
Straw	0.67%	0.73%	687	5.0

Amount of final compost to be disposed of (dry):

per day	2500	lbs/day
per cycle	90000	lbs/cycle
per year	900000	lbs/year
	450	tons/year

Calculation Assumptions

Nitrogen from Nitrocellulose is NO_3 =	176.8	(lbs/day)
Nitrogen from all other sources is NH_4 =	19.6	(lbs/day)

The Amount of Nitrogen available for vegetation uptake is given by:

$$N_a = K_N [NO_3 + k_v (NH_4) + f_n(N_0)]$$

where:

K_N =	2000	lbs/ton dry solids
NO_3 =	7.07%	(percent of NO_3 in the compost)
k_v	0.5	(volatilization factor of 0.5 or 1.0)
NH_4 =	0.79%	(percent of NH_4 in the compost)
f_n =	0.1	
N_0 =	0	(percent of organic Nitrogen in the compost)

N_a = 149.3 lbs/ton dry solids

The amount of organic compost which is available in subsuquent years is given by:

$$(N_a)_X = (N_a)_1 + K_N [f_2(N_0)_2 + f_3(N_0)_3 + \ldots + f_X(N_0)_X]$$

Application Yr	f_n	$(N_0)_n$	$f_n(N_0)_n$	$(N_a)_n$
1st	0.1	0.0000	0.0000	
2nd	0.05	0.0000	0.0000	149.3
3rd	0.03	0.0000	0.0000	149.3
4th	0.03	0.0000	0.0000	149.3
5th	0.03	0.0000	0.0000	149.3

$(N_a)_X = N_a$ since it is assumed the compost contains no organic nitrogen

$(N_a)_X = N_a$ 149.3 lbs/ton dry solids

Appendix D

Amount of Area Required for Land Application of the Final Compost Product

The amount of compost which can be applied annually is given by:

$R_N = U_N / (N_a + N_{pn})$

where:

U_N = 210 lbs/acre (Annual Nitrogen uptake by vegetation)

R_N = 1.4 tons of compost/acre

The area required for the application of the compost with the specified quantities is given by:

$A = Q_s / R_N$

Q_{day} =	1.25 tons of dry solids
Q_{cycle} =	45 tons of dry solids
Q_{year} =	450 tons of dry solids

Area/day =	0.89 acre
Area/cycle =	32 acres
Area/year =	320 acres